Performance Analysis of Different Investment Decision Models in Terms of Analytical Evaluation

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Abstract—Investment decisions are the most critical ones among all enterprises' decisions, which determines the future of enterprises. This paper aims to provide a comprehensive overview of the progress of investment decisions and compare the efficiency of four different investment models (NPV, IRR, payback period, and real option approach) based on analytical calculation and evaluation empirically. We present the background and definition of those models, as well as their basic calculation formula and simulation processing. To metric the accuracy applicability and performances of the four approaches, the empirical models are constructed and evaluated for a certain condition and the comparisons of results are demonstrated accordingly. Furthermore, based on the analysis, the advantages and preferred application situations of the four models are also discussed. Finally, some issues and limitations remaining in the approaches are outlined, which are expected to be addressed in the future. These results shed light on the implementation of the existing investment decision rules in different conditions.

Keywords- NPV; IRR; Payback period; Real option; Investment decision

1. INTRODUCTION

Investment decision-making is to choose between projects with different returns measuring by various financial tools. A proper investment choice leads to high profits, while a bad one may bring a massive loss. To improve the accuracy of decision-making, financial economists have been exploring multifarious quantitative indices. NPV and IRR are the most commonly used and representative indices, but they have also caused debates for several decades. Zhang Jing states that decisions based on IRR are easy to cause mistakes, i.e., investors should consider NPV when these two tools indicate different decisions [1]. One of the drawbacks of NPV and

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IRR is that they could be recondite for common investors. Therefore, the payback period is here to simplify the calculation when making an investment decision. For small companies or enterprises in the high growth period, the payback period is a method of much value and fitness [2]. All three methods above, however, rely on predicted cash flows. A real option is firstly introduced in 1977 by Stewart Myers, considering future uncertainty when deciding, which has become one of the main methods of investment decision nowadays [3].

A comprehensive introduction and generalization of four different investment rules will be provided in this paper to give a preliminary understanding of those investment rules. Section 2 introduces the prevailing NPV model and its constraints in the following sections and mentions an outstretched model named the Robust NPV. Afterward, Section 3 summarizes the application of IRR and its limitations. Then, Section 4 presents a supplementary method-payback period, including its definition, drawbacks, and advantages. Subsequently, Section 5 discusses the basic ideas of the real option approach and compares real option and financial options. The conclusion will be given in Section 6 eventually.

2. NPV

2.1 The Definition of NPV

Net present value is the difference between the capital expenses to obtain this asset in today's currency and the asset's present value. If the NPV for potential investment is positive, the project will be profitable and is acceptable. However, if it's negative, the project will lead to money loss and should be refused. NPV can help us decide whether an investment would make money or not [4]. The mathematical expression of this criterion is:

$$NPV = \sum_{k=0}^{n} \frac{NI_k}{(1+i)^k} \tag{1}$$

where the NI_k is the net income in the year k of the project development period, i is the discount rate, and n is the period of the investment exploitation.

The flexibility offers two important and valuable opportunities. First of all, the time value of money is quantitatively considered. Besides, there may be changes in circumstances, such as the economic pattern, the cost of acquiring assets, or the value of assets, or let us have time to collect information, as previously unavailable, which is an excellent decision to clear doubts and uncertainties [5].

2.2 The Constraints

There are three types of constraints: (I) activity completion constraints, which force each activity to be complete within a specified project period; (ii) traditional priority constraints. And (iii) capital allocation constraints.

Capital rationing restrictions (from project start to its latest finish time of each period probably a) showed that: (1) the amount of investment in all activities within a period should not exceed the period of capital available, depending on the activities of the previous plan, (2) if the project is completed in considering the period, must have enough money to pay any fines.

Ross points that there exits inefficiency in economically assessing one investment and ought to modify this criterion [6]. The past methods have some limitations, e.g., these methods do not take into account the variance and mean of the data and the correlation between them. In most cases, the nominal mean cannot properly represent the expected introduced value in the future. To deal with the influence of the uncertainty of the estimated value and the change of parameters, the researchers consider the causes of uncertainty. Various technologies which are generally divided into passive and proactive methods are proposed to deal with uncertainty [7].

2.3 The Robust NPV

They believe that the change of NPV is independent of the selective distribution of cash flow; instead, they depend on the variance of uncertain parameters. Regarding the importance of inputting cash flow variance in NPV calculation, the robust method proposed in this study considers the variance and covariance of uncertain parameters in calculating the robust net present value (RNPV) [8]. In the robust method, the variation of uncertain parameters is assumed to be in a continuous, closed, convex, bounded, and non-zero region. The concept of norm function is applied to construct the uncertainty region.

A robust model is proposed in which obtains robust amounts of NPV by selecting various norm bodies and radiuses for the U uncertainty region. The formulation can be summarized:

$$RNPV = \sum_{t=0}^{N} RNCF(1 + I) \tag{2}$$

where, RNCF is revised cash flow, which consists of net profit after-tax + depreciation - Cost of equity capital of the project = Net profit after-tax - the cost of debt capital - the cost of equity capital + depreciation; *i* is the discount rate and *n* is the period of the investment exploitation.

3. IRR

3.1 Introduction of IRR

The definition of the internal rate of return is closely related to NPV. IRR is the discount rate for which NPV equals 0. Suppose the maturity of a certain project is T, and the corresponding cash flows are equal to CF_T, then the definition, as well as the calculating model of IRR, is shown below like this:

$$CF_0 + \frac{CF_1}{1+IRR} + \frac{CF_2}{(1+IRR)^2} + \ldots + \frac{CF_T}{(1+IRR)^T} = 0 \tag{3}$$

After the project is taken, the initial investment will be recovered through annual net revenue [9]. The implicit assumption of IRR is that the recovered part of the capital will be reinvested at which the return rate exactly equals IRR. Therefore, as its name suggests, the first economical meaning of IRR is the expected return rate of the unrecovered capital until its maturity [10].

Another interpretation of IRR is the maximum limit of capital cost for a certain investment. That cost includes the risk of currency devaluation, the default risk, and all other risks that may influence the revenue of the project. For instance, if an investor gains a return rate equals to IRR and is only faced with the risk of inflation, then the project is not profitable for him if the inflation rate of the current year is higher than IRR. In this case, when making an investment decision, projects with an IRR higher than the opportunity cost of capital are preferred for their profitability to cover the capital cost and make a profit.

3.2 Limitations:

Many scholars have figured out that when comparing NPV with IRR in making investment decisions, NPV is a better choice. As have discovered, IRR rules have several limitations as follows:

a) IRR rules make a debatable presuppose that the net cash flow of every period is reinvested at IRR consistently. As stated earlier, the internal rate of return represents the expected return rate of uncovered capital, which means each cash flow has the same return rate at IRR. The probability of getting an equally high return rate will be rather low, especially for high IRR.

b) IRR conceals lending or borrowing. In the example in Table 1, project C represents lending and D for borrowing. Both have the same IRR, but investors get a return when lending and pay for interests when borrowing, which IRR fails to reflect.

TABLE I. COMPARISON BETWEEN LENDING AND BORROWING

period	0	1	NPV(r=10%)	IRR
Project C	-1000	+1500	+364	50%
Project D	+1000	-1500	-364	50%

TABLE II. PROJECTS OF DIFFERENT SCALES [11]

period	0	1	2	3	4	NPV (r=10%)	IRR
Project A	-25000	0	5000	15000	28000	9519	21.19%
Project B	-12000	5000	5000	5000	5000	3850	24.19%
A-B	-13000	-5000	0	10000	23000	5674	19.41%

c) IRR ignores the scale of the project. When choosing between mutually exclusive projects, investors considering IRR always choose the project with a higher IRR. In Table. 2, however, project A with a less IRR is more profitable for its higher NPV. Incremental investment is used to solve the problem. As project(A-B) has an IRR higher than the opportunity cost of capital r, it can also be chosen after the investor has taken B. Hence, finally, A will be taken as A-B+B=A.

d) The change of number sign in cash flows influences the uniqueness of calculation. In general, people accept that the number sign of cash flows will only change once at period 0 during the whole lifetime of the project. However, as shown in Table. 3, the sign of cash flows can change more than once in certain circumstances, which results in the multiple solutions of IRR in a single project. For a statement from Weisstein, the number of signs of cash flows is related to the number of real and positive roots of the equation. Besides, Micheal J. Osborne suggests that multiple IRRs do not represent a pitfall, for inconsistent ranking can be solved through his new equation of NPV and used to resolve the contradiction when choosing between mutually exclusive projects as well [12].

TABLE III. MULTIPLE SOLUTIONS OF IRR

period	0	1	2	NPV(r=10%)	IRR
Cash Flows	-1600	10000	-10000	-2705	25% or 400%

4. PAYBACK PERIOD

4.1 Introduction of payback

Both NPV and IRR rules mentioned above are both very handy and popular rules but still have their limitations. To gain a more comprehensive and multidimensional understanding of certain projects or to meet some special requirements, companies often look at a lot more measurements of the project's attractiveness. Among all those supplementary methods, the payback period is a highlighted one [13].

Let's start with a simple example. In Table 4, project A involves initial spending of $25000(C0=-25000) followed by cash inflows during the next four years except for year1. Since cash inflows from year2 and 3 sum up to $20000, which is less than $25000, and it is not until yeaar4 that all cash inflows could offset the initial investment. Thus the payback period for project A is 4 years. In the same way, the payback period for project B is 3 years.

TABLE IV. PAYBACK PERIOD AND NPV SOLUTIONS FOR PROJECTS A&B

Project	C0	C1	C2	C3	C4	Payback Period (years)	NPV at 10%
A	-25000	0	5000	15000	28000	4	9519
B	-12000	5000	5000	5000	5000	3	3850

According to the results, the payback period is calculated by counting how long it takes before the cumulative cash inflows offset the initial cash outflow.

$$\sum_{t=1}^{r} C_t - C_0 = 0 \quad (4)$$

Projects that could recover their initial investment within some specified period would be accepted while others would be sifted out. For instance, if the cutoff period is four years, project A is exactly qualified. However, if the cutoff is two years, then it isn't.

Back to the example, the net present value rule tells us to accept project A but to reject project B since the net present value of project A is larger than that of project B. If the company used the payback rule with a cutoff period of three years, then it would accept only project B. Whereas, if it used the payback rule with a cutoff period of four or more years, it would accept both A and B projects. Thus, the payback rule gives different answers from the net present value rule in this example despite different cutoff periods.

$$NPV(A) = -25000 + \frac{5000}{1.1^2} + \frac{15000}{1.1^3} + \frac{28000}{1.1^4} = 9519 \quad (5)$$

$$NPV(B) = -12000 + \frac{5000}{1.1} + \frac{5000}{1.1^2} + \frac{5000}{1.1^3} + \frac{5000}{1.1^4} = 3850 \quad (6)$$

4.2 Drawbacks of payback

The payback rule sometimes generates false conclusions mainly due to the following reasons: Firstly, it ignores timing and gives equal weight to all cash inflows before the cutoff date. Secondly, it considers only cash flows before the cutoff period. Since it ignores all cash inflows generated after the cutoff, some projects with considerable profits may be wrongly dismissed in the long run. Therefore, a company must decide on a reasonable cutoff date when using the payback rule. Additionally, it only pays attention to the investment recovery period of the project but fails to give us any explicit information about the project's profitability.

4.3 Advantages of payback

The payback rule is indeed quite popular among modern companies despite its apparent drawbacks and limitations. Several possible explanations have been demonstrated following. Firstly, it is a common consensus that a certain limited group does not make investment decisions of people such as the senior management of a company [14]. Instead, they need to be discussed by people from all parts of the firm who have different levels of financial knowledge. The payback rule is one of the easiest and most understandable ways to share an idea or project’s profitability. Additionally, the payback rule is especially preferred and frequently applied when there’s limited access to capital at present since those companies or managers may have little confidence in their future ability to pay off. Therefore, they would often invest in more short-payback projects to make quick profits.

5. REAL OPTION

5.1 Value of flexibility

The NPV, IRR, and payback period methods mentioned above are based on discounted cash flows analysis, using predicted cash flows during the life of a project under a specified discount rate to assess the financial availability of the project. Nevertheless, the real cash flows in the future can be different from the prediction because of uncertainty that may not be considered at the beginning of the project. Investors can change the investment decision in a particular stage of the project to maintain benefits and reduce losses. For instance, the management team may decide to abandon the project if a loss is made during the project life to avoid further loss. Similarly, managers can expand the project scale to gain more benefits when satisfactory profit is created.

Line charts can illustrate the impact of decision flexibility on expected NPV in Fig. 1. On most occasions, management's flexibility increases the value of the project by cutting loss or increase profitability. Therefore, the traditional distribution of NPV (Fig. 1(a)) changes to asymmetry distribution (Fig. 1(b)). Meanwhile, the expected NPV1 increases to adjusted NPV2.

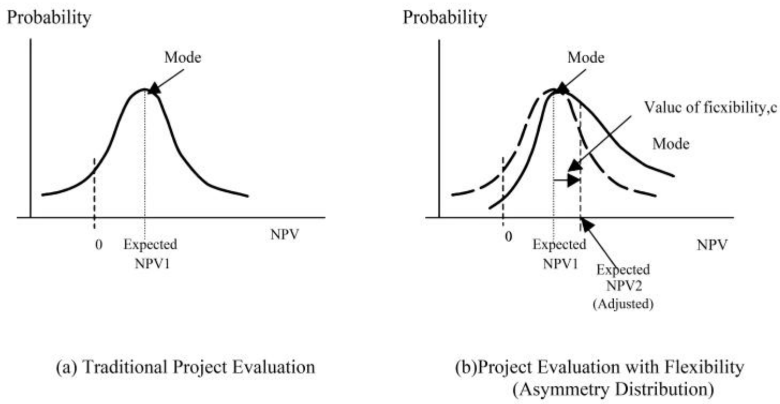

Figure 1. Illustration of the value of flexibility [15]

5.2 Real option approach

5.2.1 Basic ideas of real option approach

Nowadays, the real option approach has been developed to value the flexibility of projects and used by corporations to estimate the project value more accurately in a changing market. Managers can make further decisions according to the actual conditions of the project. All these choices can be considered as real options whose value can increase or decrease the project value. For example, managers have an opportunity to delay the investment until the market condition of the project is profitable or satisfactory for the company; managers also have an option to contract the scale of the project to maintain the profit at a better level.

5.2.2 Financial option vs. Real option

Financial options are options on financial assets. Typical financial options can be divided into call option, which gives investors an option to buy a stock at an exercise price, and put option, which enables investors to choose whether to sell a stock at the exercise price in the future. In the 1970s, Black and Scholes published the B-S option pricing model [16]. They claimed that the option price is in relation to the maturity of the contract, price in the current market, risk-free interest rate, strike price, and variance of return. The formula of option pricing model:

$$c = P_a N(d_1) - P_e N(d_2) e^{-rt} \tag{7}$$

where c is the Value of the call option; P_a is the stock's current price; P_e is the exercise price; r is the risk-free interest rate; t represents the maturity of the contract, N denotes the probability distribution function for standard normal distribution. The amounts of d_1 and d_2 are given by:

$$d_1 = \frac{\ln\left(\frac{P_a}{P_e}\right)+\left(r+\frac{s^2}{2}\right)}{s\sqrt{t}} \tag{8}$$

$$d_2 = d_1 s\sqrt{t} \tag{9}$$

Here, s is the standard deviation. Then the formula of a put option:

$$p = c - P_a + P_e e^{-rt} \tag{10}$$

The Black-Scholes option pricing model is also widely used to value real options. In analogy with the five important variables for financial options in the BSOP model, real options have corresponding variables, such as the variance of return, time to expiration, etc. Let us take the option to delay investment as an example (Fig. 2):

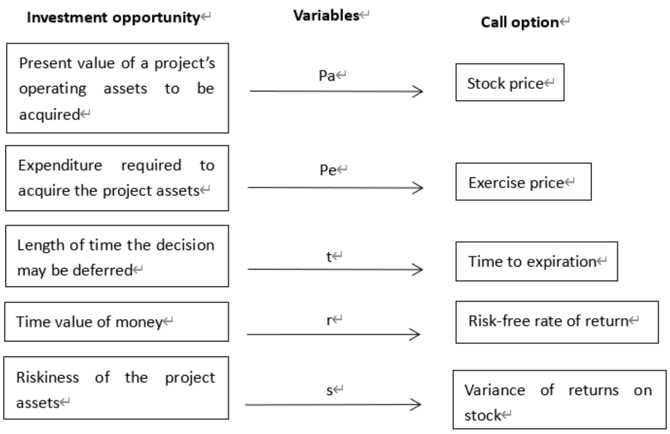

Figure 2. The analogy between financial option and real option pricing model. Reconstructed of the Figure. 2 in Ref. [15].

The deferral can be considered as a call option since it may increase the value of the project. From the graph, the present value of the project can be considered the current stock price in the financial market. The cost of the project assets is the strike price, duration of the deferral is the time to expiration. In addition, the risk-free rate of return can measure the time value of cash flows. The riskiness of the project assets is in analogy with a variance of returns on the stock. Therefore, the value of the option to delay investment can be estimated by the B-S option pricing model, so as an option to expand or contract, abandon option, etc. Nevertheless, the B-S model still has certain assumptions. For instance, it assumes that there is no transaction cost or taxes, the risk-free rate and variance are constant over the option's life, and the options are European. Managers should consider these assumptions before using the real option approach to make a decision.

6. CONCLUSION

In the real world, NPV, IRR, and payback period are used as investment criteria by the majority of companies and organizations. All three methods have specified advantages, e.g., NPV can reflect the scale of projects, while IRR and payback period are more understandable for investors. However, they cannot value the flexibility of the future cash flows generated by the project. More and more organizations have applied real option theory nowadays to value potential opportunities for the project. Estimating options on real assets makes the investment decision more accurate in the changing environment, even though the real option method also has assumptions that may affect the valuation. In the future, besides the discounted cash flow methods, approaches like real options used to measure a project's uncertainty should be applied more widely in making investment decisions.

In terms of investigating the investment decision-making process, we demonstrate the four methods under certainty and uncertainty. The significance of this is to solve the contradiction between various methods. It is precise because investment decision-making greatly impacts enterprise development and even national economic construction, i.e., the usage of investment decision-making methods for analysis is a crucial topic. Under different conditions, different investment objectives will affect the investment decision-making methods. If we blindly adopt a unified investment decision-making method for different investment decision-making contents, the timing method is correct but cannot achieve the ideal investment results. Only through in-depth analysis of each investment method can one obtain the most intuitive, correct, and detailed investment analysis to make the investment decision of maximizing income. These results offer a guideline for optimal investment decisions for contemporary corporations.

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